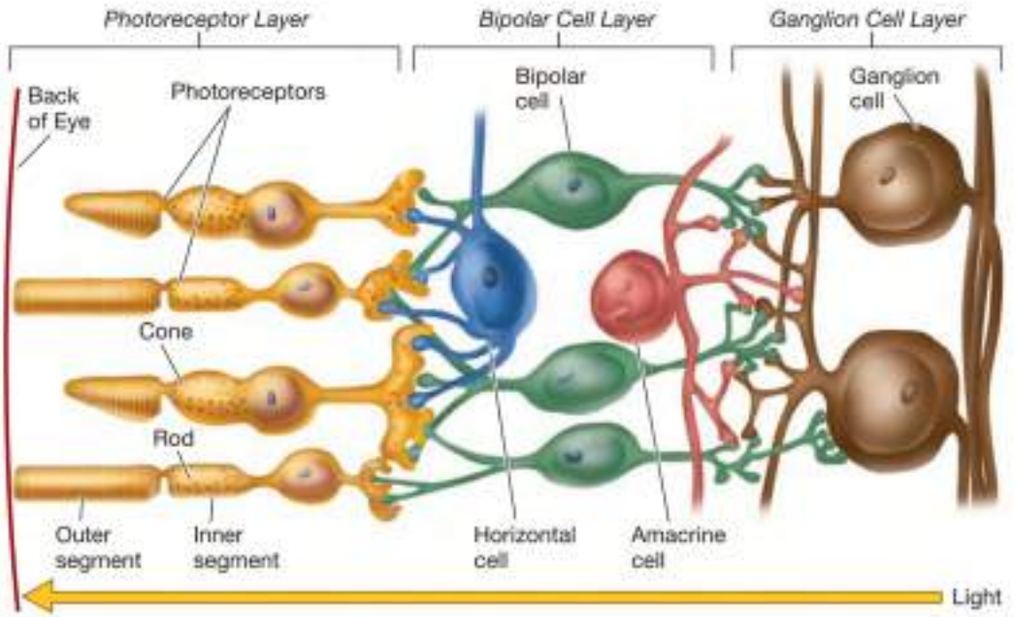
Figure 6.7 Details of Retinal Circuitry

Source: Adapted from Dowling, J. E., and Boycott, B. B. (1966). Organization of the primate retina: Electron microscopy. *Proceedings of the Royal Society of London, B, 166*, 80–111.



amacrine cells, both of which transmit information in a direction parallel to the surface of the retina and combine messages from adjacent photoreceptors. (See Figure 6.7.)

Transduction

LO 6.5 Summarize the process of transduction.

Sensory transduction occurs in the photoreceptors and allows light to be converted into a change in membrane potential. Remember that changes in membrane potential can be excitatory (depolarizing) or inhibitory (hyperpolarizing). The first step in this chain of events that eventually leads to visual perception involves a special chemical called a photopigment. **Photopigments** are embedded in the **lamellae**—thin plates of a membrane that make up the outer segment of photoreceptors. Each photoreceptor consists of an outer segment connected by a cilium to the inner segment, which contains the cell nucleus.

A single human rod contains approximately 10 million photopigment molecules. The molecules consist of two parts: an **opsin** (a protein) and **retinal** (a lipid). There are several forms of opsin; for example, the photopigment of human rods, **rhodopsin**, consists of *rod opsin* plus retinal. Retinal is synthesized from vitamin A, which explains why carrots, which are rich in this vitamin, are said to be good for your eyesight. In some cases of vitamin A deficiency, supplementing with this vitamin can improve some aspects of rod-based vision (Whatham et al., 2008).

ROLE OF HYPERPOLARIZATION IN TRANSDUCTION

Photopigments transduce light energy into changes in membrane potential. When a molecule of rhodopsin is exposed to light, it breaks into its two constituents: rod opsin and retinal. In vertebrates, splitting the photopigment triggers a cascade of intracellular events that *hyperpolarize* the photoreceptor membrane. Most other types of sensory receptors (such as hair cells in the ear for audition) become *depolarized* by stimuli. One way to understand transduction in the visual system is to think about the photoreceptors as "darkness detectors." When the receptors experience *darkness*, they respond by depolarizing. When they experience light, they respond by hyperpolarizing. For a review of hyperpolarization and depolarization, see Chapter 2.

In the vertebrate retina, photoreceptors provide input to both bipolar cells and horizontal cells in a circuit. Photoreceptors and bipolar cells do not produce action potentials. Instead, their release of neurotransmitter (glutamate) is regulated by their membrane potential. Depolarizations increase the release of neurotransmitter, and hyperpolarizations decrease it. In the dark, photoreceptors are depolarized and constantly release glutamate into synapses with bipolar cells. In the light, photoreceptors are hyperpolarized, and less glutamate is released into synapses with bipolar cells. (See Figure 6.8.)

Bipolar cells have two different responses to the presence of glutamate. ON center bipolar cells are hyperpolarized by glutamate, while OFF center bipolar cells are depolarized. The ON and OFF center bipolar cells then synapse with ganglion cells and influence *their* rate of firing. Light shining on the photoreceptor can produce a variety of responses from bipolar and ganglion cells as the transduced message begins to make its way out of the retina and to the brain for additional visual processing.